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## MINI APPLIANCE LEAKAGE CURRENT INTERRUPTER

### BACKGROUND OF THE INVENTION

The present invention relates generally to ground fault safety devices and more specifically to appliance leakage current interrupters.

It is well known for electrical appliances, such as hair dryers, to draw electrical power through connection to a power source, such as an electrical outlet. Specifically, the electrical appliance (which serves as the load of the electrical system) is connected to the power source by a pair of current-carrying wires. The pair of current-carrying wires typically include a hot wire and a neutral wire, the pair of wires having equal but opposite magnitudes under normal conditions.

On occasion, the electrical system may experience a ground fault condition while the load is connected to the power supply. A ground fault condition occurs when the differential between the values of the currents of the two wires exceeds a predetermined value. Often a ground fault will occur if the hot line becomes inadvertently grounded. A ground fault condition can result in a loss of power to the electrical appliance because current is unable to flow to the load. As a consequence, an excessive amount of current tends to flow into the ground conductor of the electrical system which, in turn, creates dangerous voltage levels at points in the circuit that should be at ground potential. This condition can result in potentially dangerous electrical shocks, which could seriously injure an individual.

Accordingly, ground fault safety devices are commonly employed in such electrical systems to eliminate ground fault conditions. One type of ground fault safety device is the ground fault circuit interrupter (GFCI). Another type of ground fault safety device is the appliance leakage current interrupter (ALCI). Ground fault

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060	2061	2062	2063	2064	2065	2066	2067	2068	2069	2070	2071	2072	2073	2074	2075	2076	2077	2078	2079	2080	2081	2082	2083	2084	2085	2086	2087	2088	2089	2090	2091	2092	2093	2094	2095	2096	2097	2098	2099
1990	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060	2061	2062	2063	2064	2065	2066	2067	2068	2069	2070	2071	2072	2073	2074	2075	2076	2077	2078	2079	2080	2081	2082	2083	2084	2085	2086	2087	2088	2089	2090	2091	2092	2093	2094	2095	2096	2097	2098	2099

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One well known and commonly used ALCI is made by Tower Manufacturing Corporation and is shown U.S. Design Patent number 356,066 to C.P Rao et al. This ALCI includes a fault detection circuit to detect the presence of a ground fault condition. The fault detection circuit includes a five layered transformer which

monitors the current differential between the hot and neutral lines. The fault detection circuit also includes an integrated circuit (IC) chip which generates a output fault signal whenever the imbalance between the currents in the hot and neutral lines exceeds a predetermined value. The output fault signal is sent to a relay circuit which is coupled to a pair of switches, one switch being located in the hot line and one switch being located in the neutral line. When the magnitude of the output fault signal generated by the transformer exceeds a predetermined value, the IC chip applies power to the relay circuit which causes the pair of switches to open the hot and neutral lines. The IC chip used in the circuit is Raytheon Corporation chip number RV4145.

The circuit of the ALCI described above is mounted within a generally rectangular housing having a top, a bottom, a front end and a rear end. The housing is attached to the appliance by an electrical cord which extends into the housing from the rear end. A pair of prongs (blades) extend out from the bottom of the housing and are sized, shaped and spaced away from each other so that they can be inserted into the sockets of an electrical outlet, thus making contact and closing the circuit.

The circuit components of the above identified ALCI are typically through-hole mounted on one side of a single-sided circuit board which is positioned within the housing and all the conductive connection lines and pads are soldered on the other side of the circuit board. In particular, it should be noted that the IC chip is mounted on the first side of the circuit board through plated-through hole technology.

In U.S. Patent number 5,198,955 to Wilner, there is disclosed a miniature circuit interrupter for interruption of a primary circuit, the circuit interrupter formed or molded with a plug, connector or the like, the plug or connector being non-serviceable and the circuit interrupter therein being sealed and watertight.

Another patent of interest is U.S. Patent number 4,567,544 to Ronemus et al.

## SUMMARY OF THE INVENTION

It is an object of this invention to provide a new and improved ALCI.

It is another object of this invention to provide an ALCI as described above wherein the circuitry of the ALCI is contained within a generally rectangular housing which is very small in size.

It is yet another object of this invention to provide an ALCI as described above for use with an appliance such as a hair dryer.

It is still another object of this invention to provide an ALCI as described above wherein the ALCI is constructed so as to also serve as a plug for connecting the appliance to an electrical outlet.

It is another object of this invention to provide an ALCI as described above which has a limited number of parts, which is easy to use and which is inexpensive to manufacture.

Accordingly, there is provided an appliance leakage current interrupter (ALCI) for interrupting the flow of current through a pair of lines extending between a source of power and a load, said appliance leakage current interrupter comprising a circuit breaker having a pair of normally closed switches, one switch being located in each of said lines between the source of power and the load, a relay circuit for selectively opening the pair of normally closed switches, a fault detection circuit for detecting the presence of a ground fault condition in said pair of lines and for causing said relay circuit to open said circuit breaker when said fault condition detected exceeds a predetermined value, said fault detection circuit comprising an integrated circuit chip and a transformer, and a single-sided circuit board having a first side and a second side, the second side having a pattern of conductive paths, wherein said integrated circuit chip is surface mounted on the second side of said single-sided circuit board.

According to one embodiment of the present invention, said appliance leakage current interrupter further comprises a pair of contact prongs and a housing, the housing having a top, a bottom, a front end and a rear end, the pair of prongs extending out from the front end of the housing.

According to another embodiment of the present invention, said appliance leakage current interrupter further comprises a pair of contacts prongs and a housing having a top, a bottom, a front end and a rear end, the pair of prongs extending out from the bottom of the housing.

Various other features and advantages will appear from the description to follow. In the description, reference is made to the accompanying drawings which form a part thereof, and in which is shown by way of illustration, specific embodiments for practicing the invention. These embodiments will be described in sufficient detail to enable those skilled in the art to practice the invention, and it is to be understood that other embodiments may be utilized and that structural changes may be made without departing from the scope of the invention. The following detailed description is therefore, not to be taken in a limiting sense, and the scope of the present invention is best defined by the appended claims.

## BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings wherein like reference numerals represent like parts:

Fig. 1 is a perspective view of a prior art appliance leakage current interrupter;

Fig. 2 is a circuit diagram of the prior art appliance leakage current interrupter shown in Fig. 1;

Fig. 3 is a side section view of the prior art appliance leakage current interrupter shown in Fig. 1;

Fig. 4 is a perspective view of a first embodiment of a miniature appliance leakage current interrupter constructed in accordance with the principles of the present invention;

Fig. 5 is a circuit diagram of the miniature appliance leakage current interrupter shown in Fig. 4;

Fig. 6 is a top exploded view of the miniature appliance leakage current interrupter shown in Fig. 4;

Fig. 7 is a bottom exploded view of the miniature appliance leakage current interrupter shown in Fig. 4;

Fig. 8 is a side section view of the miniature appliance leakage current interrupter shown in Fig. 4;

Fig. 9 is a perspective view of a second embodiment of a miniature appliance leakage current interrupter;

Fig. 10 is a top exploded view of the miniature appliance leakage current interrupter shown in Fig. 9; and

Fig. 11 is a bottom exploded view of the miniature appliance leakage current interrupter shown in Fig. 9.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Figs. 1-3 show one type of prior art appliance leakage current interrupter (ALCI) which is well known in the art, the ALCI being identified by reference numeral 10. It is the function of ALCI 10 to detect and, if necessary, eliminate ground fault conditions. Appliance leakage current interrupter 10 is sold by Tower Manufacturing Corporation as model number SD1028, the design of which is represented in U.S. Design patent number 356,066 which issued on March 7, 1995 to C.P. Rao et al.

Circuitry 10-0 of ALCI 10 is mounted on a printed circuit board within a generally rectangular shaped housing 10-1 which serves as the electrical plug for an electrical appliance. Circuitry 10-0 includes a fault detection circuit 10-2, a relay circuit 10-3, a power supply circuit 10-4, a circuit breaker 10-5 and a test circuit 10-6.

The housing of ALCI 10 has a length  $L_1$  of approximately 2.20 inches, a width  $W_1$  of approximately 1.95 inches and a thickness  $T_1$  of approximately 1.95 inches. It should be noted that due to industry regulations, the size of the housing for the plug is deemed too large to safely accommodate electrical prongs which extend from the housing at 180 degrees from the electrical cord of the appliance, thereby limiting potential applications. The particular details of ALCI 10 will be discussed below only as they compare to the present invention.

Referring now to Figs. 4 through 8 and first to Fig. 5, there is shown a circuit diagram for a miniature appliance leakage current interrupter (ALCI) constructed in accordance with the principles of the present invention, the ALCI being designated as reference numeral 11. Appliance leakage current interrupter 11 includes a circuit breaker 13, a relay circuit 15, a fault detection circuit 17, a power supply circuit 19 and a test circuit 21.

Appliance leakage current interrupter 11 is electrically connected to the pair of current carrying wires which connect a load to a power source. The pair of current carrying wires include a hot line (or wire) H and a neutral line (or wire) N, lines H and N having equal but opposite magnitudes under normal conditions. It is the function of ALCI 11 to interrupt the flow of current through lines H and L upon detection of a ground fault condition, which will be discussed in detail below.

Circuit breaker 13 comprises a pair of normally closed switches SW1 and SW2 which are located in the hot and neutral lines, respectively, between the power source and the load. Switches SW1 and SW2 remain in the closed position until such time as fault detection circuit 17 detects the presence of a ground fault condition, at which time switches SW1 and SW2 open. Once open, switches SW1 and SW2 remain open until a reset button (to be discussed in detail below) is manually depressed to close the switches.

Relay circuit 15 comprises a solenoid 23, a silicon controlled rectifier (SCR) 25 and a capacitor 27. Solenoid 23 is connected to hot line H and serves the function of selectively opening switches SW1 and SW2 upon the detection of a ground fault condition. Rectifier 25 is connected to both solenoid 23 and fault detection circuit 17 and serves to energize solenoid 23 upon the detection of a ground fault condition. Rectifier 25 is preferably a model PO110DA rectifier sold by Tencor Corporation. Capacitor 27 is connected in parallel to rectifier 25 and fault detection circuit 17 and serves as a noise suppression filter. Capacitor 27 preferably has a value of 10nf and acts to filter out noise occurring in circuit 11 which could mistakenly cause rectifier 25 to energize solenoid 23. In contrast to ALCI 11, ALCI 10 includes a pair of capacitors which are connected in parallel, the capacitors having values of 2.2 uf and 0.01uf. Because the relay circuit of ALCI 11 includes one less capacitor than ALCI 10, ALCI 11 is able to be slightly reduced in size.



Fault detection circuit 17 comprises a transformer 29, an integrated circuit (IC) chip 31, a coupling capacitor 33, a noise filter capacitor 35, a timing capacitor 37 and a feedback resistor 39. It is the function of fault detection circuit 17 to detect the presence of a ground fault condition in the hot and neutral lines. Furthermore, upon the detection of a ground fault condition, fault detection circuit 17 generates an output signal which is applied to relay circuit 15 which opens circuit breaker 13.

Transformer 29 includes a laminated core 41 and a multiturn secondary sense winding 43. Laminated core 43 is generally ring shaped and includes three laminated layers or rings. In contrast, the laminated core of ALCI 10 includes five laminated layers; therefore, the transformer of ALCI 11 is substantially smaller than the transformer of ALCI 10. Hot wire H and neutral wire N serve as the primary winding and are wrapped around core 41 twice in order to build up the primary. In contrast, in ALCI 10, wires H and N are only wrapped around the core of the transformer once. Secondary winding 43 is connected to coupling capacitor 33 which, in turn is connected to pin 2 of IC chip 31. In addition, winding 43 is connected to pin 3 of chip 31 and noise filter capacitor 35 which, in turn, is connected to pin 4 of chip 31. It is the function of transformer 29 to sense current differentials between hot line H and neutral line N and induce an associated output to secondary winding 43. Coupling capacitor 33, which preferably has a value of 10 uf, serves to couple the AC signal of secondary winding 43 before the signal reaches chip 31. Noise filter capacitor 35, which preferably has a value of 0.1 uf, serves to filter out unwanted noise signals before such signals reach chip 31. Integrated circuit chip 31 is preferably an RV4140 model chip manufactured by Ratheon Corporation. In contrast, ALCI 10 uses IC chip model number RV4145, manufactured by Ratheon Corporation.

Pin 4 of chip 31 is connected to feedback resistor 39 which, in turn, is connected to pin 1 of chip 31. Pin 4 of chip 31 is also connected to timing capacitor

37 which, in turn, is connected to pin 8 of chip 31. Pins 6 and 7 of chip 31 are connected to capacitor 27 and rectifier 25. It is the function of ground fault interrupter IC chip 31 to amplify the ground fault signal generated by transformer 29 and provide an associated output signal at pin 7. Feedback resistor 39, which preferably has a value between 100Kohms and 470Kohms, serves to establish the minimum threshold value of a ground fault condition which will cause an output ground fault signal at pin 7 to pass to relay circuit 15. Timing capacitor 37, which preferably has a value of 0.02 uf, serves to work in conjunction with feedback resistor 39 in determining the minimum ground fault current setting.

Power supply circuit 19 comprises a metal oxide varistor 45 and a voltage dropping resistor 47. It is the function of power supply circuit 19 to supply the AC power produced from the power source to pin 5 (the power supply pin) of chip 31. Varistor 45, which preferably has a value of 150 volts, serves to provide voltage surge suppression for circuit 11 from the power source. Resistor 47, which preferably has a value of 82Kohms, serves to supply the appropriate AC voltage required by IC chip 31. In contrast, ALCI 10 includes a rectifier bridge rather than a voltage dropping resistor. The elimination of the rectifier bridge enables the overall size of ALCI 11 to be slightly smaller than ALCI 10.

Test circuit 21 comprises a test switch 49 and a current limiting resistor 51. It is the function of test circuit 21 to provide a means for testing if appliance leakage current interrupter 11 is functioning properly. Test switch 49, which is preferably a normally open, single pole single throw switch, serves to energize the test circuit when in the closed position. Test switch 49 is opened and closed through the depression of a manually operated button 50. Resistor 51, which preferably has a value of 15Kohms, serves to provide a simulated fault current to test circuit 21, similar to a fault condition which would be detected by fault detection circuit 17.

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In use, appliance leakage current interrupter 11 detects ground fault conditions. Specifically, ground fault conditions result when the differential in the currents in the hot and neutral lines exceeds a predetermined value. For example, a ground fault condition may result from an accidental grounding of the hot line. Ground fault conditions can lead to excessive current flow which can cause dangerous voltages to be present at points that should be ground potential, which can be extremely dangerous. Fault detection circuit 17 detects the presence of a ground fault condition and generates a ground fault condition output signal which is applied to relay circuit 15. In turn, relay circuit 15 serves to open up circuit breaker 13 which opens circuit 11, thereby preventing further ground fault current to flow.

As shown in Figs. 4, 6 and 7, ALCI 11 further includes a rectangular-shaped housing 63 which is mounted onto an end of an electrical cord 65 which is connected to the load. Housing 63 includes a top portion 67 and a bottom portion 69. Top and bottom portions 67 and 69 are secured together by screws (not shown).

B A single-side circuit board 71 is mounted within housing 63. The components of the electric circuit of ALCI 11 are mounted on circuit board 71 so as to facilitate the connection of the components and so as to reduce the overall size of the unit. Circuit board 71 comprises a top (i.e. solder) side <sup>surface</sup> 73 and a bottom side <sup>surface</sup> 75. The majority of the components of ALCI 11 are mounted on bottom side 75 and extend through plated-through holes in board 71. The components are then soldered and interconnected through conductive paths and patterns which are located on top side 73.

It should be noted that IC chip 31 is mounted on top side 73 of circuit board 71. In contrast, in ALCI 10 the IC chip is mounted on the bottom side. By mounting IC chip 31 on top side 73, the density of components which are mountable on circuit board 71 is increased, thereby reducing the overall size of plug 61. Referring now to

Figs. 3 and 8, it can be seen that by placing of chip 31 on top side 73 rather than bottom side 75, transformer 29 and solenoid 23 are capable of being positioned closer to one another than in ALCI 10, thereby making ALCI 11 substantially shorter in length than ALCI 10. With the IC chip on the bottom side as in ALCI 10, the IC chip, the transformer and the solenoid must all be adequately spaced apart, which dramatically increases the overall length of the plug. It should also be noted that IC chip 31 is shown as being surface mounted on side 73. If desired, however, IC chip 31 could be mounted on side 73 of board 71 by wires and solder.

ALCI 11 also includes a prong assembly 77 for connecting the electrical components of ALCI 11 to a power supply. Referring to Figs. 6 and 7, prong assembly 77 includes a pair of neutral contact prongs (or blades) 79 which are sized and shaped so as to be fitted within the sockets of an electrical outlet. Prongs 79 extend from within housing 63 and out through bottom portion 69 at an angle of 90 degrees from the longitudinal axis of electrical cord 65. Each prong 79 is connected to a conductive bracket arm 81. Each bracket arm 81 is positioned above a conductive contact arm 83. Contact arms 83 are mounted within housing 63 such that each arm 83 pivots about a pin 85 so as to selectively contact bracket arm 81. Each contact arm 81 is connected to the circuit of ALCI 11 and, as a consequence, when contact arm 83 is pivoted out of contact from bracket arm 81, power is not supplied ALCI 11.

ALCI 11 includes a reset assembly 87 which serves to reset ALCI 11 after the detection of a ground fault condition. Reset assembly 87 comprises a reset button 89, which like test button 50, extends out through top portion 67 of housing 63. Depression of reset knob 81 causes a springed reset column 91 to move downward. Downward movement of column 91 causes an actuator 93 to pivot each of contact arms 83 out of contact from bracket arm 81. This creates an open connection in

